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Specialization and Cooperation in Scientific Research

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a long and notable history, and that it has come to be what it is by steps and stages that can be easily marked out and mastered. The moment the student gets this view of physics, his study of it takes hold of him with redoubled power because he sees himself dealing with a vast and continuing human interest. Then is the time for the laboratory method to be drawn upon to show him the technique of present-day knowledge and present-day discovery. In short, the natural and physical sciences have an enormous value as cultural subjects which has been in large part lost by bad methods of teaching and presentation. The specialist gets from his study of science all that he needs for his specialty, but science meanwhile stands apart from the general stream of cultural influence and development. Faraday and Maxwell, Huxley and Tyndall, Berthelot and Pasteur, Helmholtz and Kelvin, as well as our own Pupin and Millikan are scientific teachers of a different type. They all have in high degree the power of so interpreting science that at their hands it becomes a genuine instrument for the improvement of popular thinking and public action and a vitally important element of broad and fine culture.

NICHOLAS MURRAY BUTLER, Columbia University

**SPECIALIZATION AND COOPERATION IN SCIENTIFIC RESEARCH.**—Research must be more generally encouraged and supported. You may have thought, in my illustrations of the advantages which have been derived from research, that I gave undue emphasis to invention and commercial development. I did so purposely, for I wished to bring out a contrast. Where immediate financial returns are in sight, the keen search for profits which spurs our business life brings quick support and reward. Thus industrial research and development are coming more and more to be looked upon as shrewd business policy. Purely scientific research, which is absolutely prerequisite and basic to invention and development, is, on the other hand, generally carried on at a personal sacrifice and cramped for facilities. The average scientist has to battle against the odds of other supposedly prior duties in order to get time for concentrated thought and sustained experimental effort. . . . Whence, then is support for scientific research to be obtained?

In the first place this support should come from those same funds which support the other activities of our universities, on the ground that research is an essential element and method of education. In

the second place it will come from altruistic citizens and organizations who possess the wisdom and imagination to visualize the possibilities which research will uncover for the future. In the third place, as I have suggested, it should come from industrial and business organizations. I should like to see all such enterprises which profit directly from the work of science taxed to support research. Probably this can never be done by legal means, but its equivalent may be brought about by publicity and the force of enlightened public opinion. If, for example, a large proportion of such industries could be induced to share the burden of supporting research and this were done on a large scale, no one industry would be handicapped in respect to the others and from the widespread nature of the research thus made possible, every industry would have a reasonable expectation of obtaining something to its direct advantage in addition to the indirect benefit of general business stimulation. Such is the justification of the "Hoover Fund" which the National Academy of Sciences is attempting to raise from large industries with the strong backing of Secretary Hoover. Finally, support may come from the government, if this can rise above the pressure of political struggle and popular appeal for tax reduction, and look to the welfare of the future. True, the government is now supporting a few research agencies, but on a very niggardly scale, in very restricted fields, and with such pressure for immediate practical returns as to drive out those scientists who might do big things and almost to kill the possibility of that type of research which might have great consequences.

It has been said that civilization is measured by the degree to which the people will sacrifice present desires for the sake of future benefits. On this basis the degree to which we support research should count heavily in estimating our degree of civilization.

The second conclusion which I would draw is that: *The universities must be the chief agents and mainsprings of research.* There is no organization other than the universities where there are gathered together the men of scholarly training capable of carrying on research in the whole field of scientific inquiry. If there *were* some other suitable organization, it is there, rather than to the universities, that young men would go for research training, and this organization would at once *become* a university. Such work is undoubtedly the function of the universities.

Furthermore, it is a well-known paradox that the discoveries

which have led to the greatest practical results have not been made by the men who were seeking the practical results. The reason for this is plain. The man who is seeking a certain end is mentally circumscribed by the methods which are already known for attaining this end. He may perfect some previous process, or he may see how to apply some phenomenon or principle which has not hitherto been applied, but his mental state handicaps him in discovering anything fundamentally new. The basic research must, therefore, be a free and unfettered search for truth. It is the universities alone which can offer any considerable opportunity for such endeavor.

Besides this, it is to the universities that the industrial laboratories and government bureaus must turn for their trained men. The head of one of the largest electrical companies recently stated that the only limitation to the development and extension of his industry lay in the dearth of trained men fitted to take charge of the developments which they had in sight.

The third lesson I would draw from the experience of the past is that: *Research must proceed by specialization.* Research has always required concentration, but it did not formerly require intense specialization. Look, for instance, at Benjamin Franklin, at once philosopher, publisher, scientist, and diplomat. Even in science he did not specialize. . .

But today each individual branch of science is larger than the entire body of science of Franklin's day. The philosopher may still contemplate the entire field of knowledge and consider its inter-relationships, but no man can do creative work in the entire field. . .

With this tendency comes the necessity of a balancing movement, which is my last conclusion: *Research must become more and more cooperative.* An obvious handicap and danger of specialization is that a man may not know, and in fact now-a-days cannot know, even all the aspects and relationships of his own special field, however small. Hence, unaided, he becomes helpless through the very specialization which he hoped would give him power. The remedy for this danger lies in cooperation between workers in closely related branches of study. . .

To take just one example: Though physics is the most mathematical of the sciences, the average research physicist and the average productive mathematician speak languages unknown to each other. To make advances in one field available for progress in the other there has arisen a chain of connecting links. We have the experi-

mental physicist, the theoretical physicist, the mathematical physicist the applied mathematician and the pure mathematician. I do not believe there is a single living scientist who could at the same time classify under all six headings. There is possibly one, named Einstein who might classify under five, and there are very few who could classify in four of these groups. . .

Several solutions may, however, be suggested as of proven value and worthy of encouragement.

One of these is the encouragement of research in the so-called border-line fields such as mathematical physics, physical chemistry, biophysics, biochemistry, etc. Not only are such coordinating studies necessary, but they are, in my opinion, the most fruitful fields of investigation. Nature herself is not divided into a physical world, a chemical world, a biological world; she is a unit. These artificial distinctions have been introduced for convenience and because of our inability to see the whole field at once. . .

The necessity of coordinating border-line work is recognized by such far-sighted organizations as the General and International Education Boards and the Rockefeller Foundation which have, for example, supported the great system of National and International Research Fellowships, one of whose guiding principles is the stimulation of research in the border-line fields. In our universities further facility and encouragement should be given to men to prepare for work in these directions.

Another solution can advantageously be advanced by wise administration of the universities. There seems to be a wide-spread but ill-founded feeling that all departments of a university should be developed together and kept closely abreast. . .

Much more effective in advancing knowledge as well as in bringing distinction to the university is the policy of supporting, to the available limit, certain departments selected because of their already outstanding character, or because of the traditions and purposes of the university, or for any other reason. If these favored departments are chosen in a coordinated group, then the university becomes an active center for the development of that field and the promotion of cooperative effort. For example, one institution may choose to give *particular* facilities for advanced work in classics and languages, another in historical, economic, and social sciences, another to physical and biological sciences, etc. . .

Through concentration of effort in a coordinated group of depart-

ments, a university has the opportunity not only to correct the dangers of over-specialization, but also to take a strategic position in fulfilling its obligations to society. . .

However, there is another direction in which more effective organization is possible within the universities themselves! Departments of a somewhat more flexible nature than those to which we are accustomed and which could, more than now, be built around one or two outstanding men in the department, could give these men an opportunity for organization and concentration of effort which is now rarely possible. This would, of course, require careful selection of men. In this matter of organization of departments around the most productive and outstanding men, of taking for granted that they will have research assistants to increase the efficiency of their labors, of selection and recognition of men on the basis of merit and promise rather than seniority, and of wise procedure in the selection of men to fill important posts, America is far more backward and bound by tradition than are those European countries in which scientific achievements have been most rapid. It may surprise you, for instance, as it did me, to learn that in America, the land of wealth and opportunity, there is no university which is able to offer a salary equal dollar for dollar to salaries which universities even in war-ridden Germany will offer to secure the outstanding men. As is the tendency in other things American, our tendency to standardize, which is so useful in some directions, is interfering with our ability to recognize, secure, and do our best. This situation in our universities is, I believe, a grave one if we set as our ideal the best possible achievement. . .

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RESEARCH AND TEACHING.—A considerable part of the criticism aimed at the modern medical school boils down to the charge that too much emphasis is placed upon research, and too little attention given to the teaching of existing knowledge. Defense against this accusation involves a general discussion of the functions of the departments which instruct in the preclinical sciences, and calls for some consideration of the assertion—frequently coupled with such criticism—that “research and education are not the same thing” and had better be separated. This last suggestion, we believe, is a pernicious one chiefly because it fails to recognize the importance